Atomic Structure

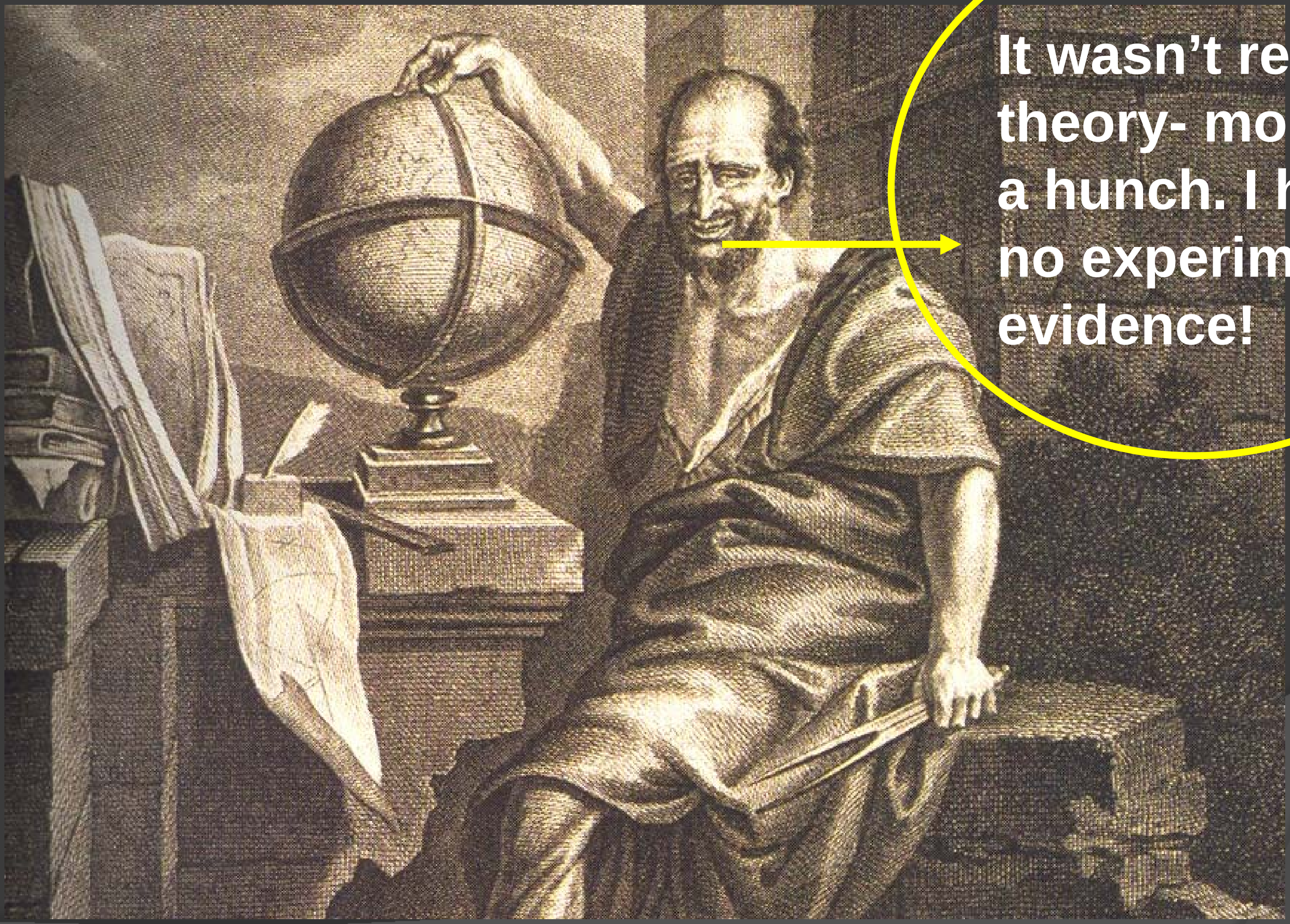
An introduction to atomic structure (with a bit of history thrown in)

- Way Back- no such thing as an experiment
- Lots of “philosophers”
- Any ideas were based on thoughts, not evidence.
- First attempt at an atomic theory was **Democritus**

Democritus said...

- Imagine a piece of gold.
- Divide it in half
- Keep doing this and eventually….
- You'll get to a piece that can't be divided any more
- The Greek word for "indivisible" = atomos
- Not really a theory based on experimental evidence- more of a "hunch."

Our Guy Democritus



It wasn't really a theory- more like a hunch. I had no experimental evidence!

The basis for this

- It seemed logical
- Not based on any experimental evidence
- He would have drawn a sphere
- The Greeks liked spheres
- There is a difference between philosophy and science

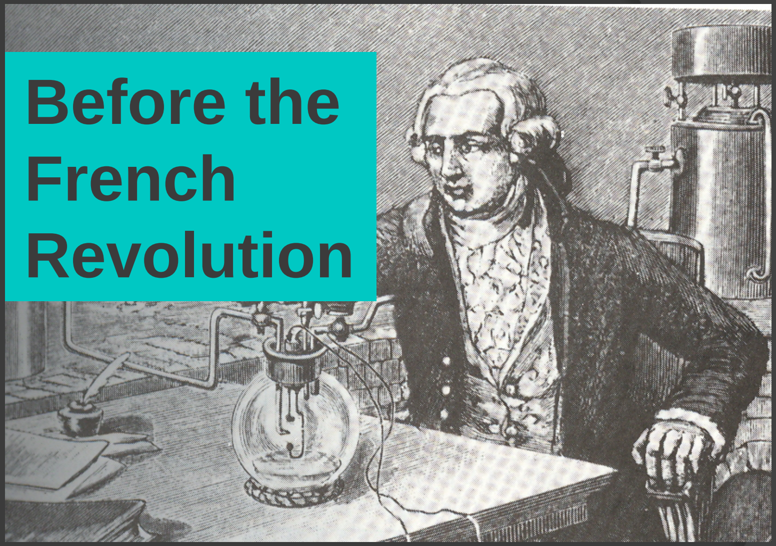
Antoine Lavoisier's Contribution (late 1700's)

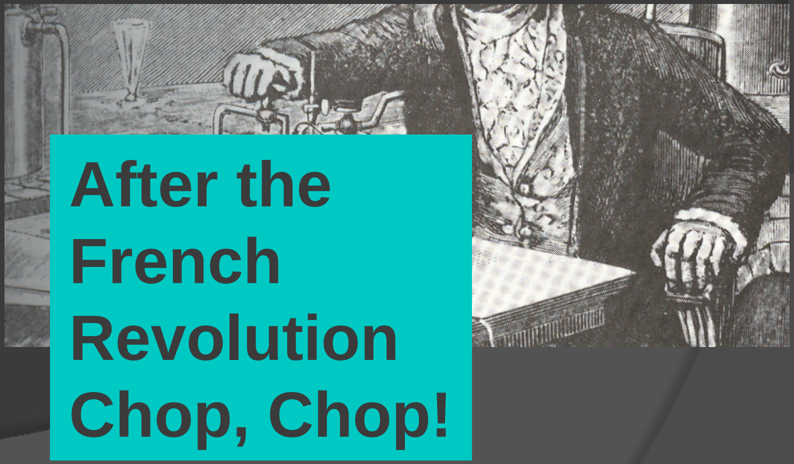
- Made chemistry a science
- Based conclusions and theories on **experimental evidence** and not just conjectures or hunches that "seemed" right

A recreation of Lavoisier's Lab

Lavoisier 2

- Not a good idea to be a tax collector around the time of the French revolution





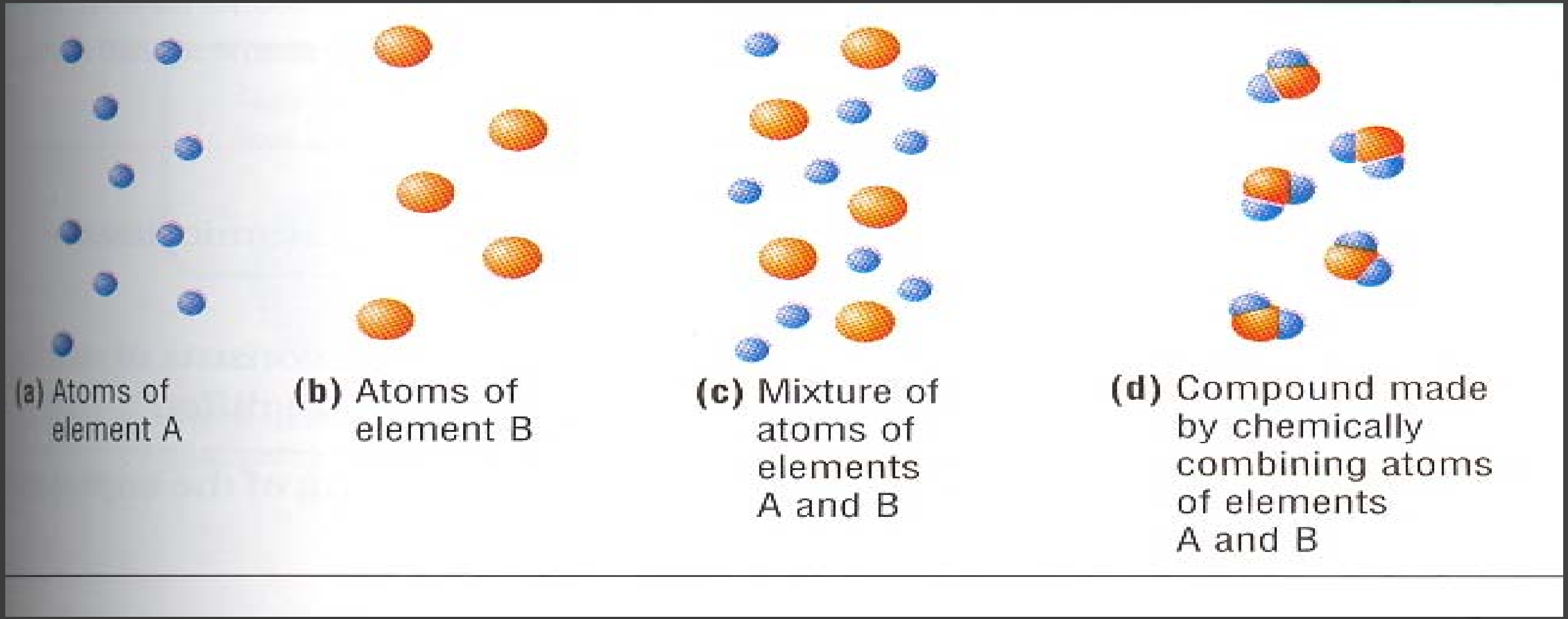
John Dalton

- First theory in a scientific sense
- Side info- old name for colorblindness was “Daltonism”.
- Named for Dalton as he recognized and described the condition.

Dalton's Atomic Theory

- Based his theory on experimental evidence
  - All elements are composed of indivisible particles called atoms
  - All atoms of an element are identical.
  - Atoms of different elements are different
  - Atoms can mix physically or combine chemically in simple whole number ratios to form compounds
  - In reactions, atoms rearrange what they are combined with, but an atom never changes into a different type of atom

Visually

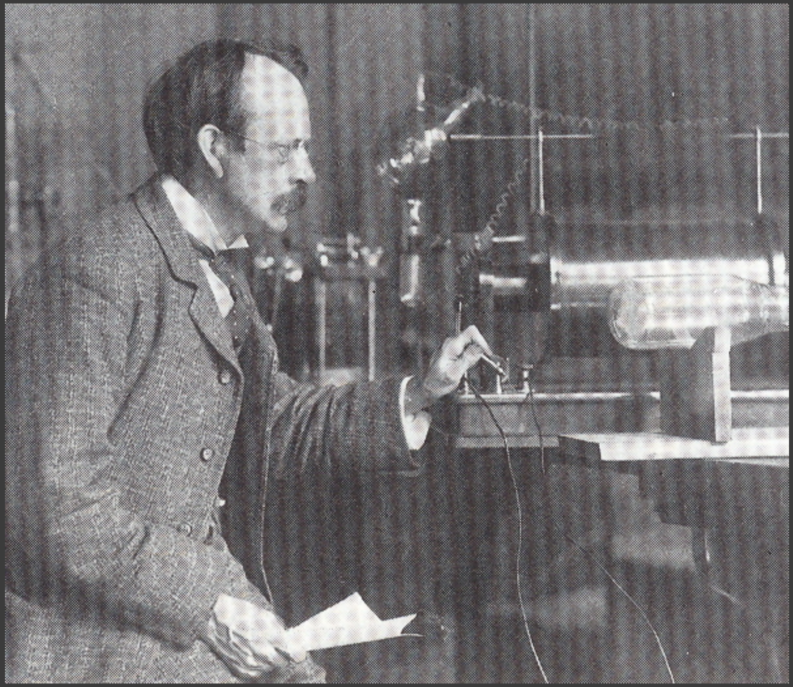


(a) Atoms of element A
(b) Atoms of element B
(c) Mixture of atoms of elements A and B
(d) Compound made by chemically combining atoms of elements A and B

2000 Years After Democritus (give or take a few)…

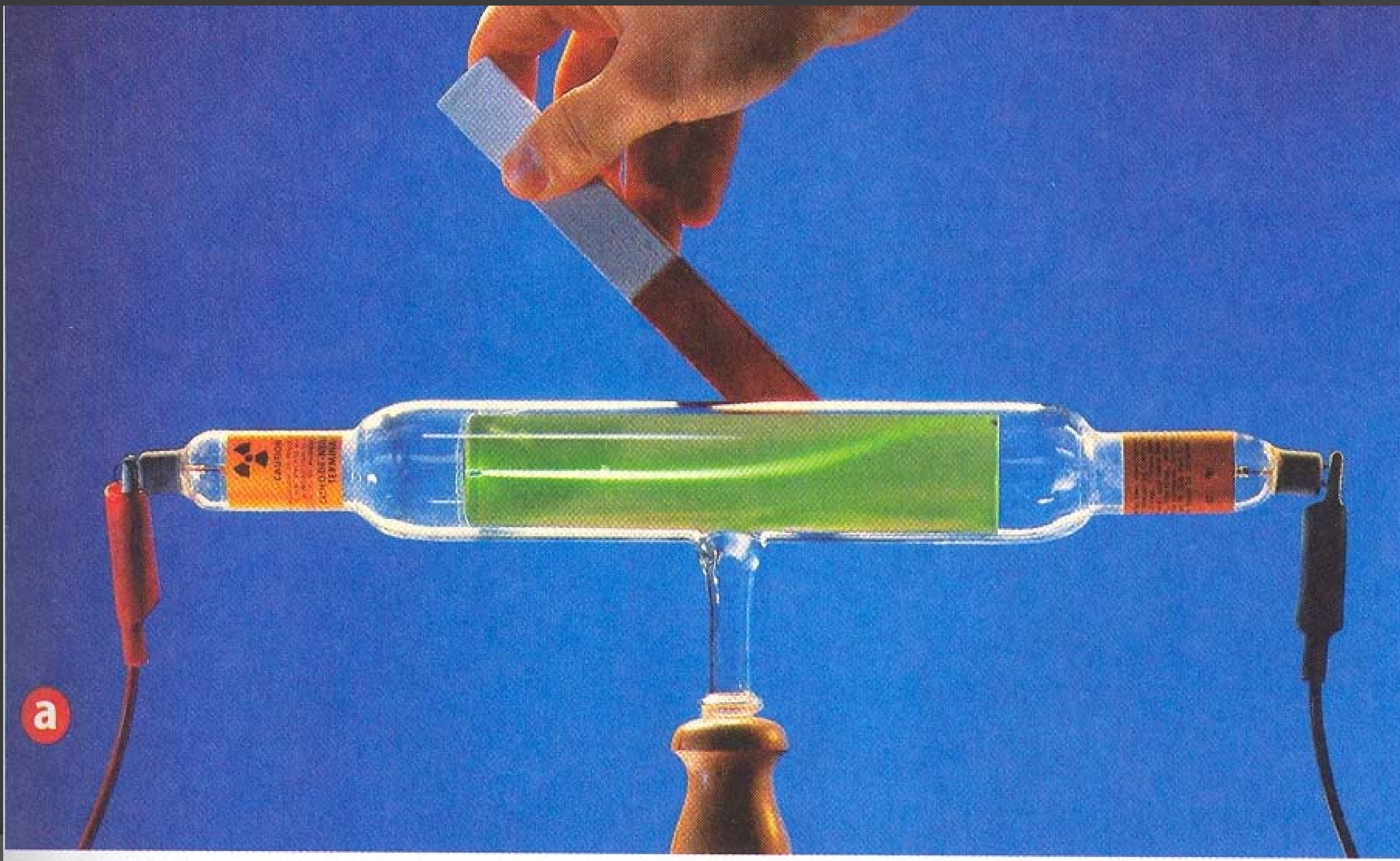
- The first experimental evidence that atoms had “parts” to them
- Generically these parts are called **subatomic particles**
- We will learn about three of these particles (the ones that matter to chemistry and that have practical applications today)

Thomson (1897)

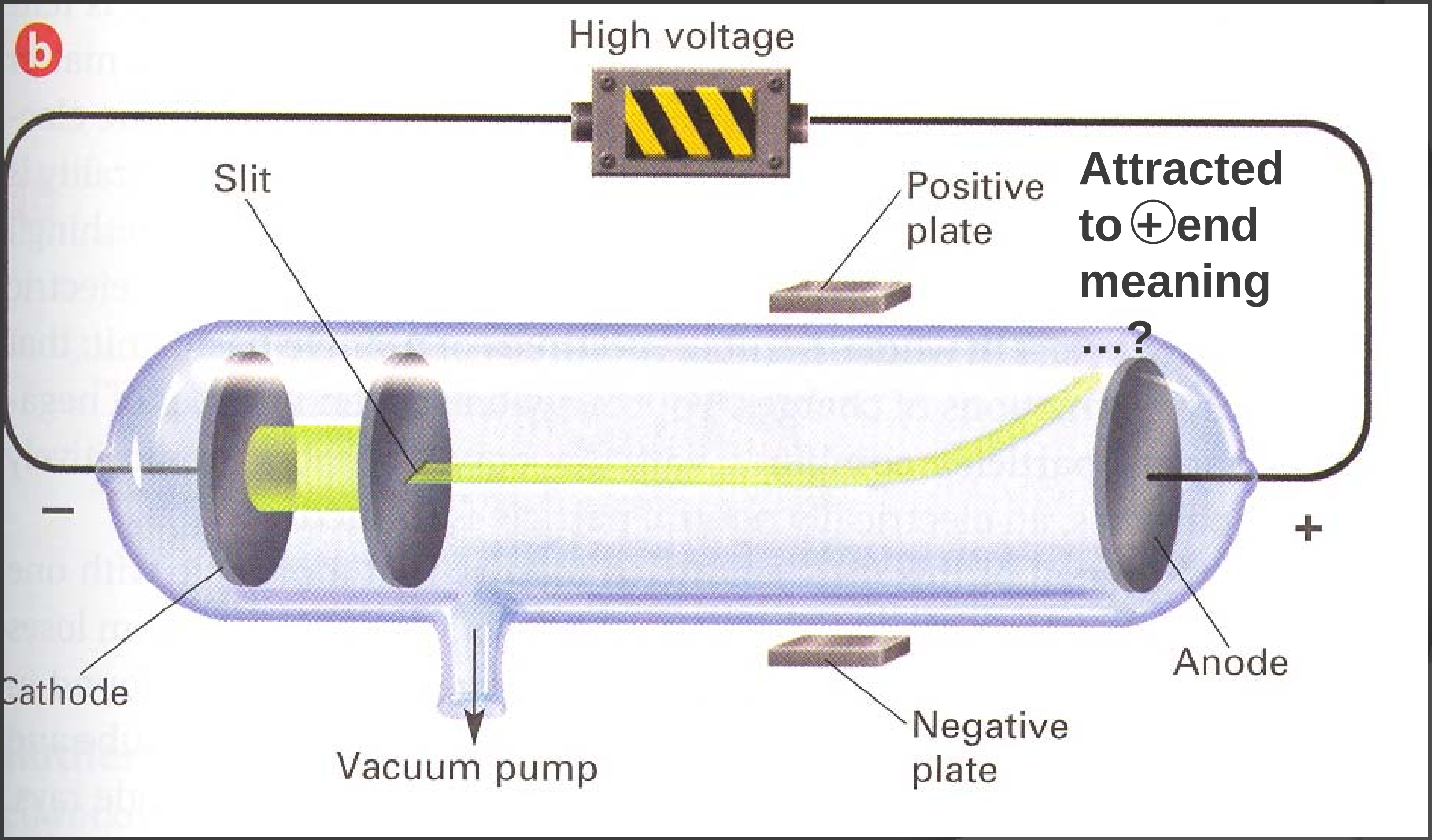


- Discovered a subatomic particle in all types of materials that he tested
- This particle had a negative charge
- He called it the electron (electrical particle)

Cathode Ray Tube



The experiment



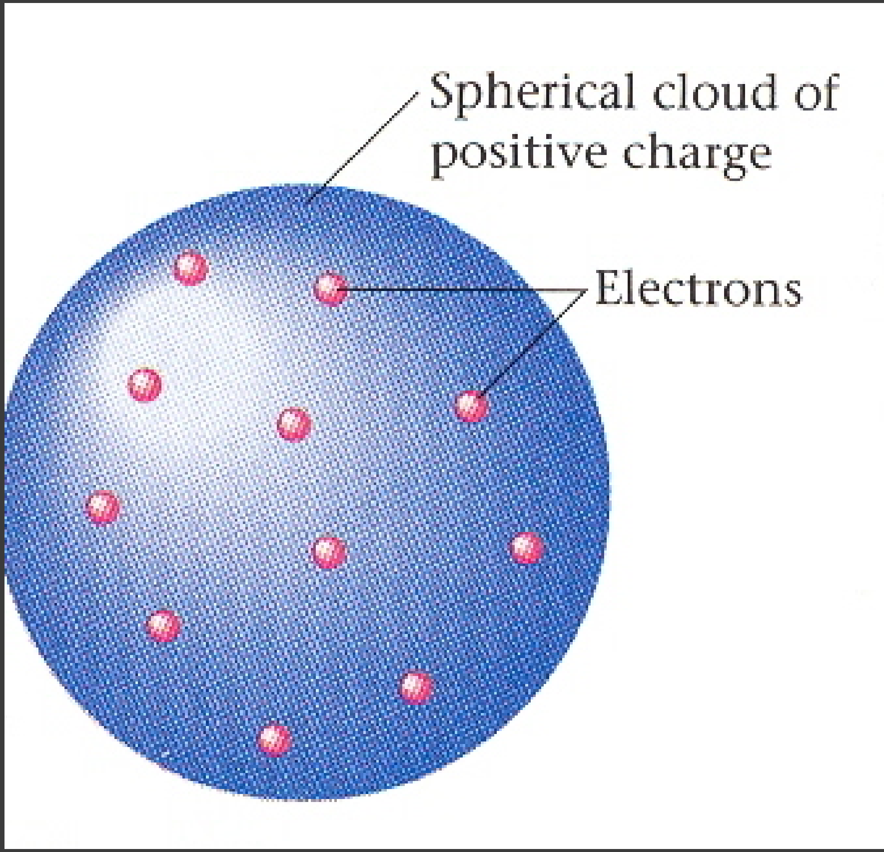
What his experimental evidence showed

- These negatively charged particles were present in every substance that he tested
- They must be a fundamental component of matter
- While others had hypothesized about particles, this was the first experimental evidence of them

Thomson’s Model

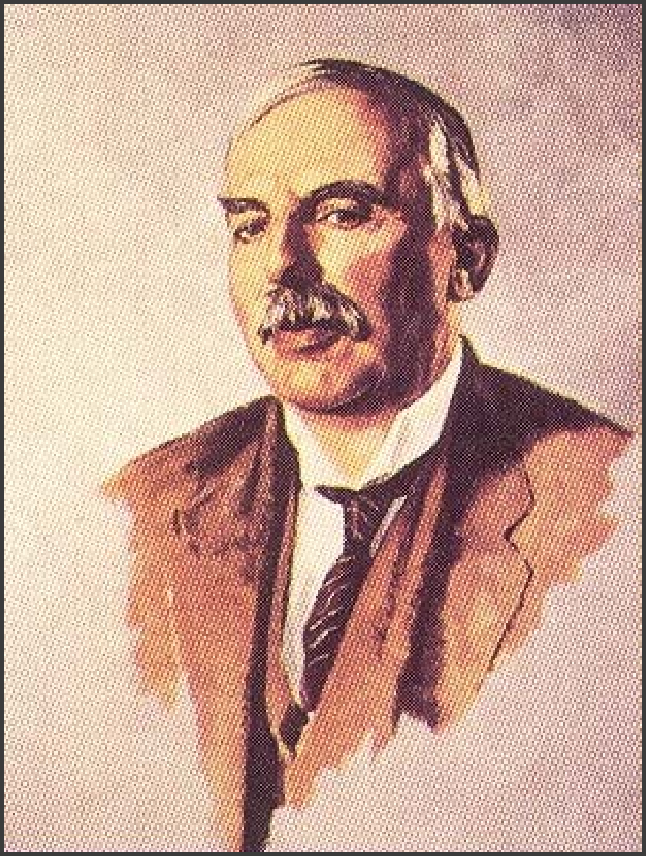
- The “Plum Pudding model”
- Atoms were known to be neutral overall
- He knew of a specific negative particle
- Therefore, there had to be something positive
- He had no evidence of a positive particle so it was not part of his model

Plum Pudding Model



- Positive “matrix”
- Negative particles
- No other detail
- Fit with experimental evidence available at the time

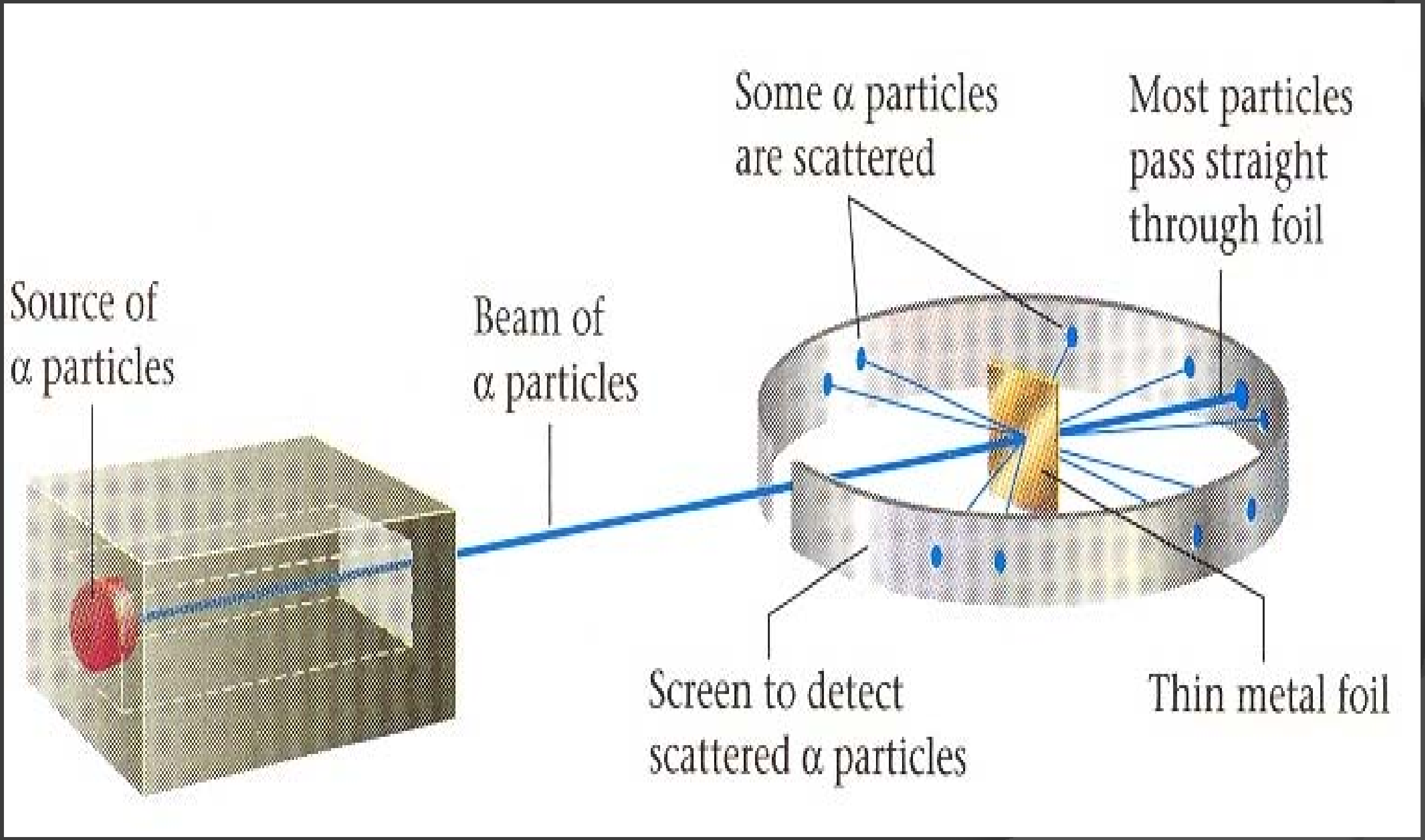
Ernest Rutherford



Rutherford’s Gold Foil Experiment

- Trying to support the “Plum Pudding Model”
- Use alpha particles (which are positively charged) as projectiles and shoot them toward a very thin layer of gold (he repeated the experiment with other metals and got similar results)
- Hypothesis was that the alpha particles would “plow through” the “plum pudding matrix unaffected – think of shooting a bullet through a jello fruit mold

The Experiment



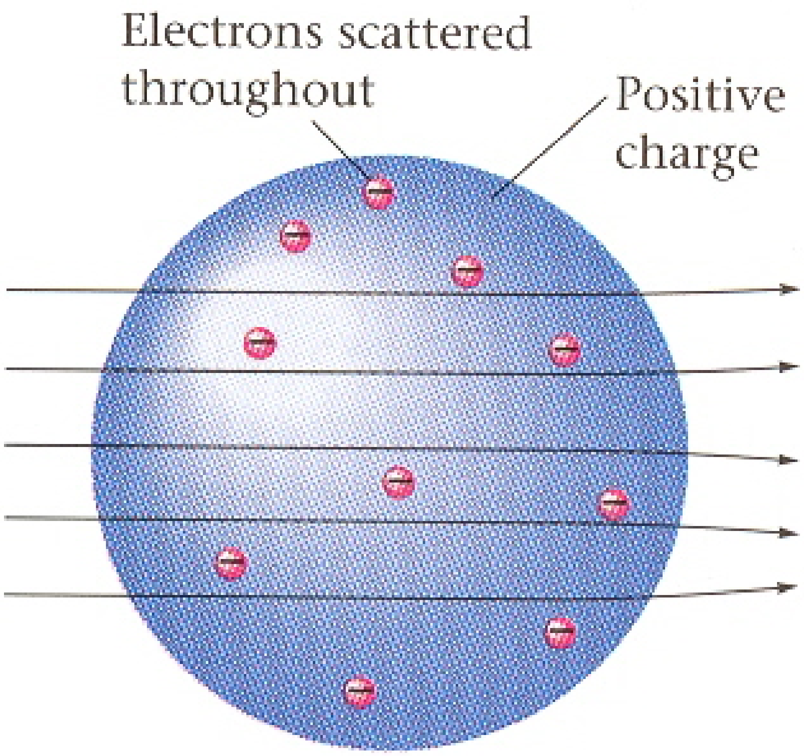
The Results

- The vast majority of the particles went right through, unaffected just as he hypothesized
- A small percentage were deflected off at an angle
- A very small percentage rebounded almost directly back
- None were “lost” or unaccounted for

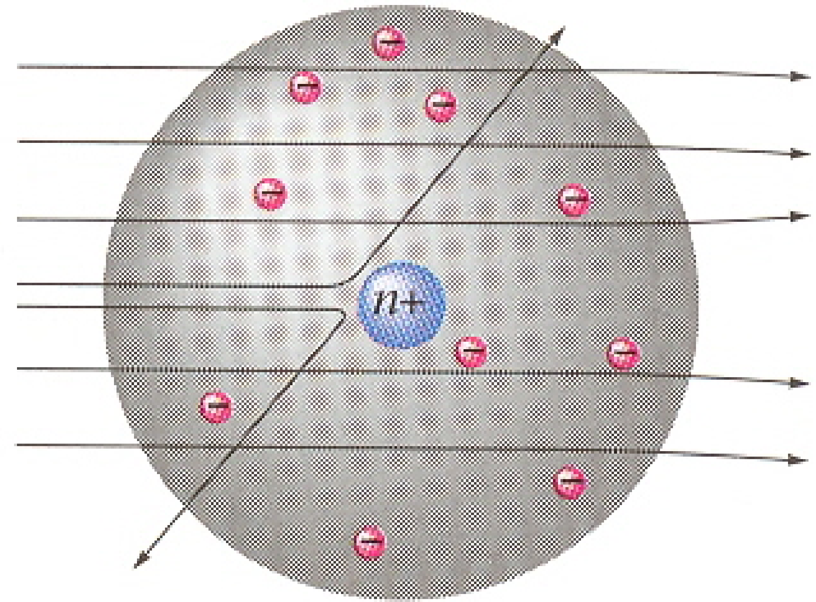
The Conclusion

- Most of the atom is empty space
- Evidence to support this is that most alpha particles were not affected by the “solid” gold foil
- There must be something **small** and **positive** that caused some alpha particles to be deflected or shot right back
- (make sure you understand why the experiment supports these two facts)

Or…



If the Plum Pudding Model Had been correct. This was Rutherford's Hypothesis



Model of an atom after the Gold Foil Experiment.

How small is the nucleus?

- Imagine expanding a single atom to the size of a pro football stadium
- The nucleus would be about the size of a soccer ball placed on the 50 yard line
- That is small!
- Rutherford said that hitting the nucleus was like finding “a fly in a cathedral”

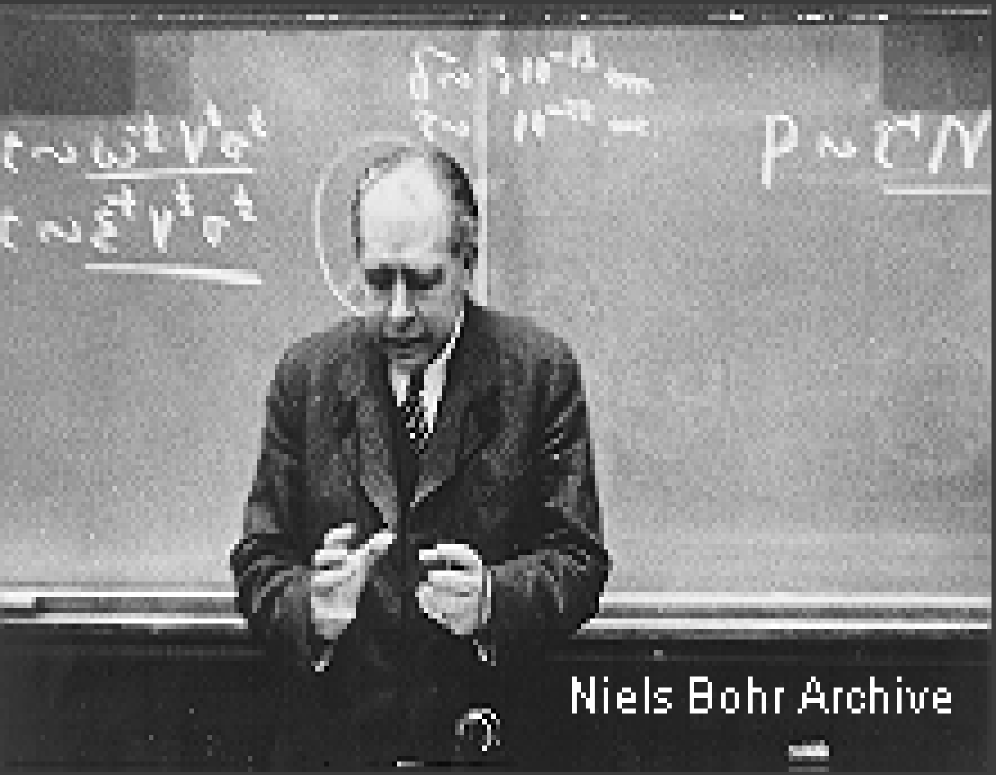
Not too long thereafter

- A specific positive particle was discovered called the **proton** (positive particle)
- A neutral particle was discovered that explain the total mass of atoms. This was the neutron.
- Why was the **neutron** discovered last (about 1932)?

Neutron

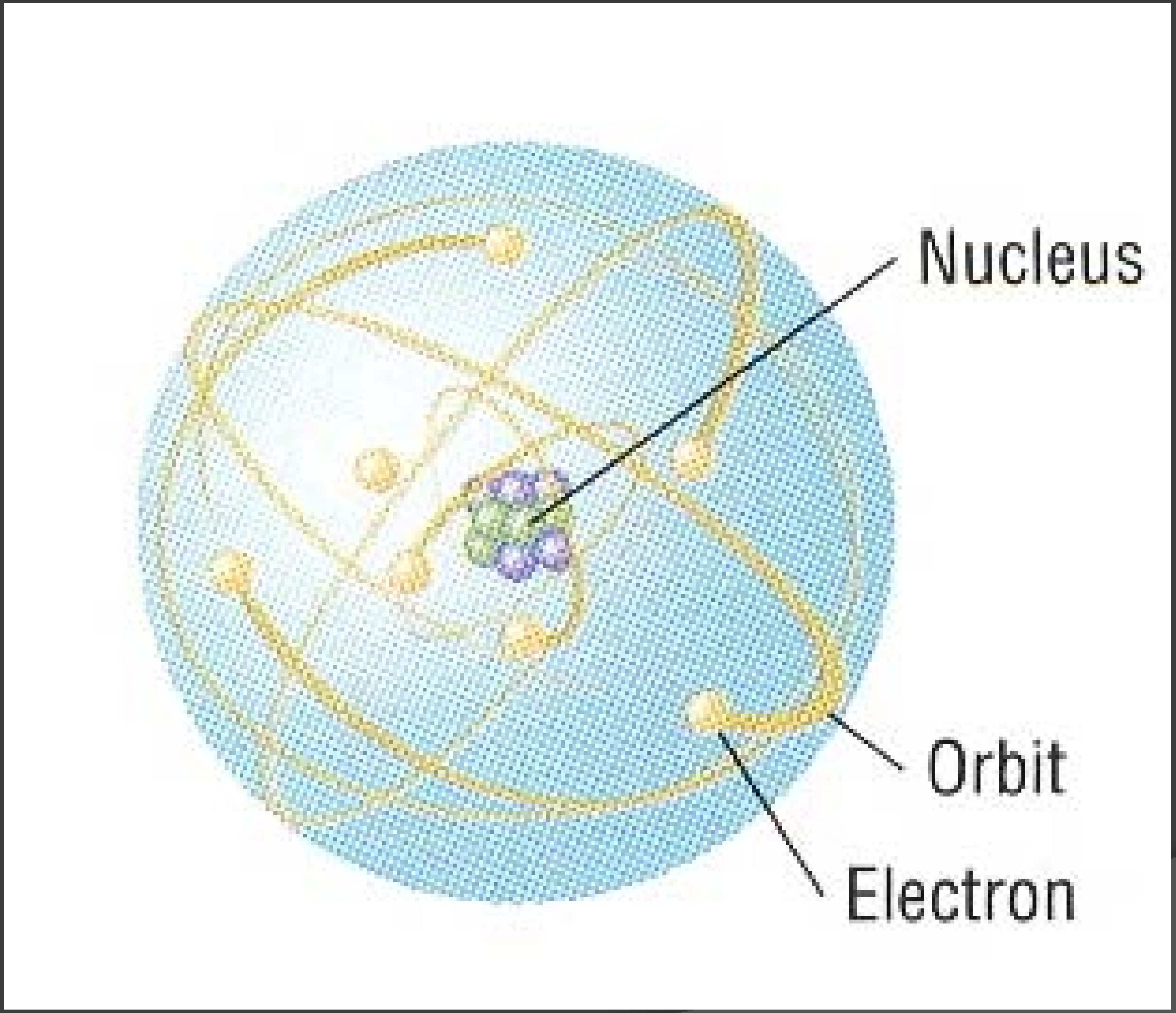
- Discovered by James Chadwick in 1932
- Your grandparents were likely alive then!
- “Neutral” partcile- could use electrical of magnetic properties to identify it

The Bohr Model



- Sought to explain the electrons in more detail
- Often called the planetary model
- Was very popular and still exists in many people's minds

Bohr Model 2



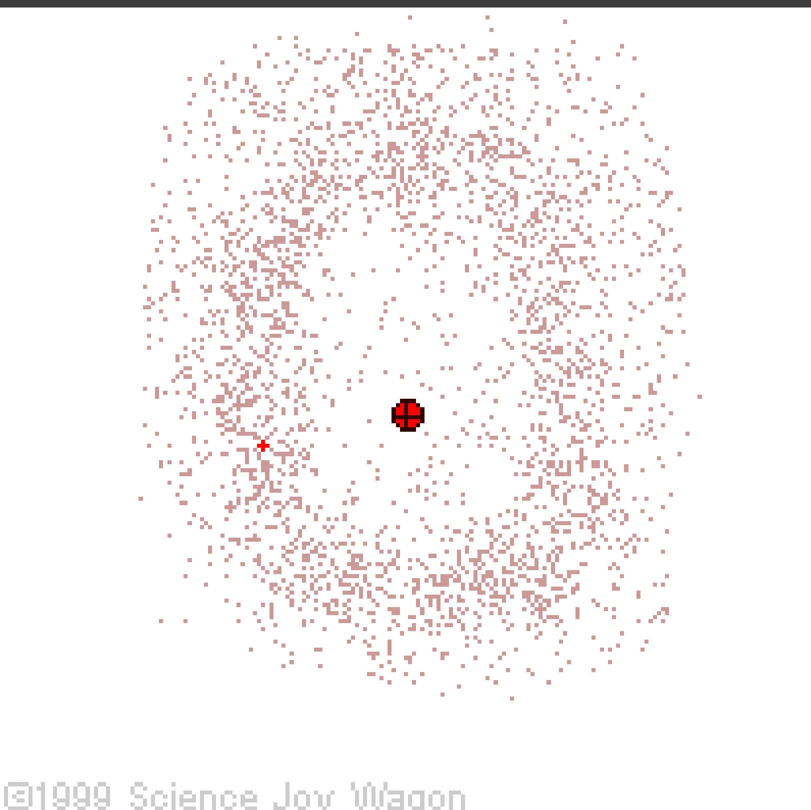
Alas

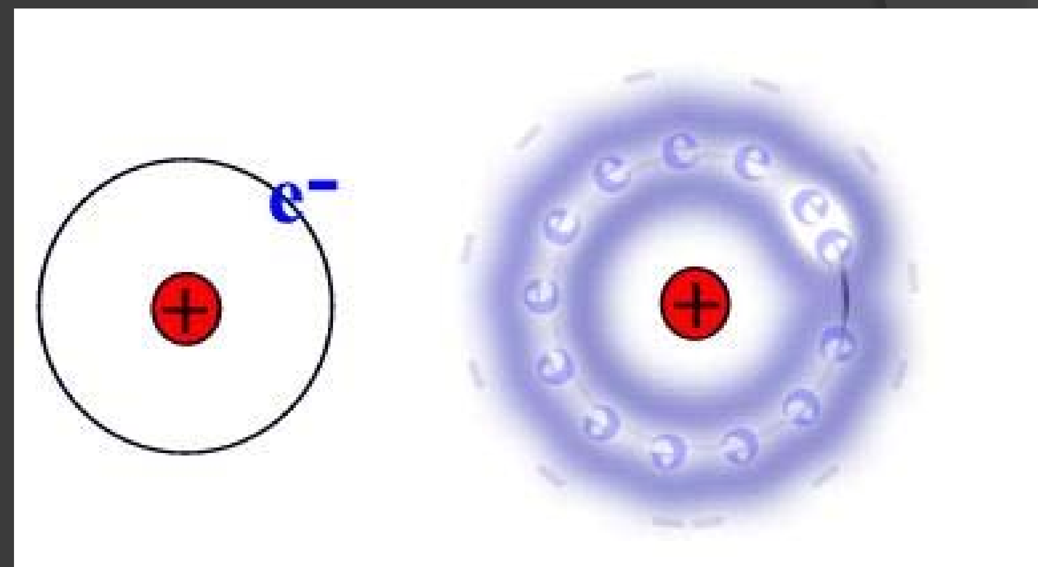
- Its is wrong
- Atoms are not like little solar systems
- We can’t predict or know the exact location and path of an electron
- We will learn much more about this when we study quantum mechanics

Current (quantum) model

- Often called an electron cloud model
- Protons and neutrons are in the very small, very dense nucleus (almost all of the mass of the atom is there).
- Electrons are located outside of the nucleus

Something Like One of These





The parts of the atom

Name	Symbol	Charge	Mass*	Location	Discoverer
Proton	p^+	+1	1 amu	Nucleus	Goldstein
Neutron	n	0	1 amu	Nucleus	Chadwick
Electron	$\overline{e}$	-1	~0 amu	Outside nucleus	Thomson

The actual masses are 1.7×10^{-24} g for the proton and neutron and 9.1×10^{-28} g for the electron. "amu" is a convenient way of describing relative masses.

Interpreting Atomic Symbols

- On a periodic table every atomic symbol is accompanied by two numbers
- Some have more than this but those two numbers (the **atomic number** and the **mass number**) are always given
- You are not to memorize any of those numbers, but you will learn how to interpret and apply them

Interpreting Atomic Symbols 2

- Officially, the **atomic number** is supposed to be placed at the bottom left of the atomic symbol and **mass number** at the top left

Mass Number → 7

Atomic Number → 3

$^{7}_{3}Li$

Interpreting Atomic Symbols

- The atomic number = the number of protons in the nucleus of the atom
- It is the atoms “ID #”
- It also equals the # electrons in the atom
- Why? (atoms are neutral so # + = # -)
- Mass number = # protons and neutrons in the nucleus (mass of electrons is so small we ignore it in most cases)

Interpreting Atomic Symbols 4

- So the number of neutrons can be found by the following method

	Mass #	# protons + #neutrons
-	Atomic #	# protons
-	=	# neutrons

- For the Li atom previously that would be 7- 3 = 4 neutrons

A couple of examples

$^{31}_{15}P$

Atomic # = 15

Mass # = 31 amu

protons = 15

electrons = 15

neutrons = 31-15 = 16

$^{80}_{35}Br$

Atomic # = 35

Mass # = 80 amu

protons = 35

electrons = 35

neutrons = 80-35 = 45

5 Facts you can get from every atomic symbol

- Atomic Number
- Mass Number
- Number of protons
- Number of neutrons
- Number of electrons
- (100+ elements x 5 = more than 500 facts you can get from atomic symbols)

You are not expected to memorize any numbers on the periodic table. Just to know how to use them to get information.

Isotopes

- In reality, all atoms of an element are not identical
- They all have the same number of protons
- They can vary in the number of neutrons
- Forms of an atom with different numbers of neutrons are called isotopes
- Same atomic number but a different mass number

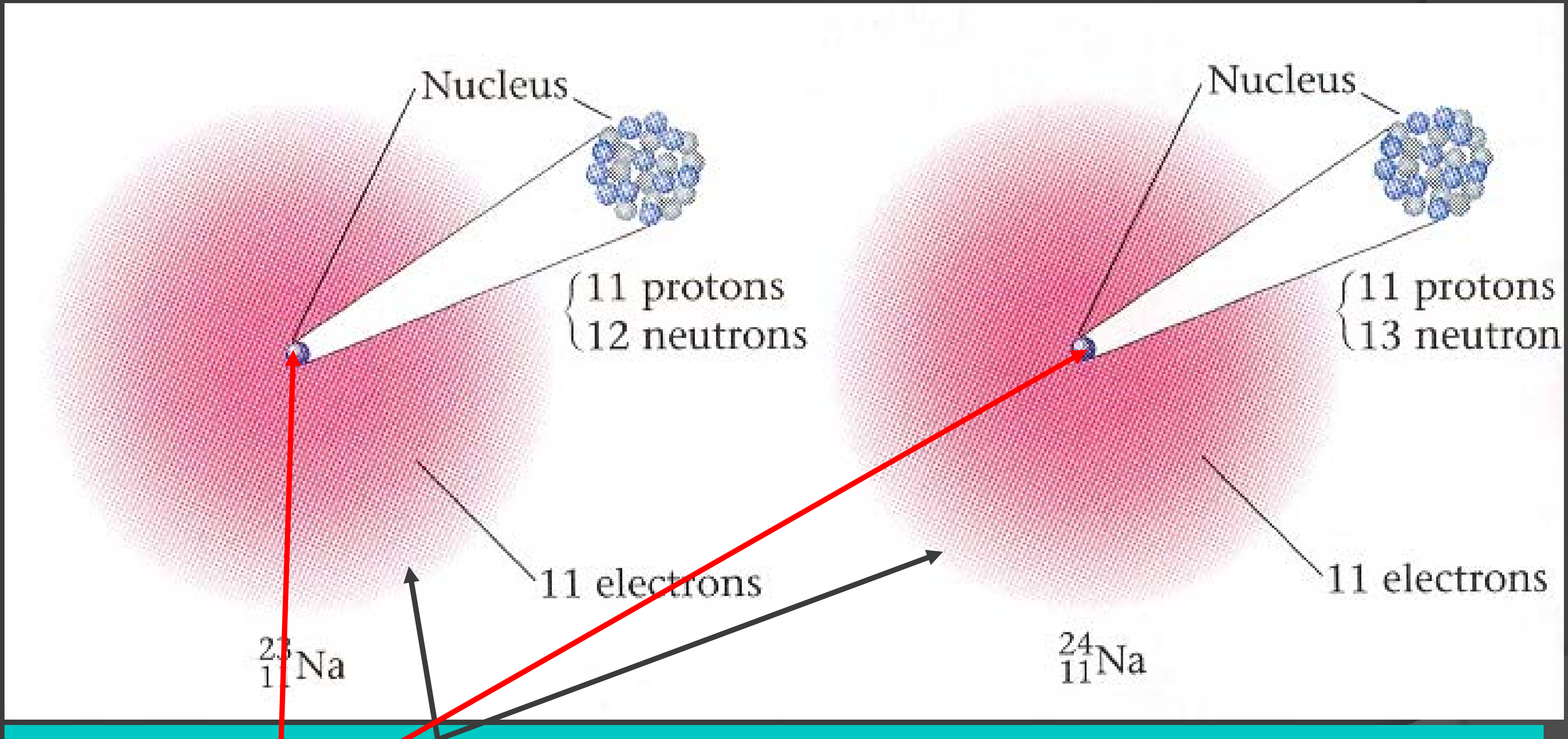
Isotopes 2; naming

- An isotope is named for its mass number
- The isotope of carbon with a mass number of 14 is called carbon-14
- The atomic number does not get stated explicitly because once you say Carbon, the atomic number must be 6.
- Isotopes of an atom act the same chemically

Isotopes 3

- Some atoms have only one isotope while others may have a dozen
- The most common isotope is still an isotope. In other words there is not a “normal” atom (like Carbon-12) and then isotopes. Carbon-12, carbon-13 and carbon-14 are all isotopes of carbon.

If You Could See an Atom



Note the electron cloud around the nucleus and the small size of the nucleus compared to the entire atom. If drawn to scale the nucleus would be a miniscule dot in this image.

Example

Isotope	Symbol	Atomic #	Mass #	# p^+	# n	# e^-
Lead-207	Pb-207	82	207	82	125	82
Lead-208	Pb-208	82	208	82	126	82
Lead-209	Pb-209	82	209	82	127	82

Specific Isotopes vs averages

- The periodic table shows the average of all the isotopes of an elements, based on their relative amounts.
- Just like your final grade is an average based on whole numbers, the average atomic mass on the table is an average
- Isotopes are not present in = amounts.
- Usually one isotope predominates

Average Atomic Mass Calculations 1

- This is a weighted average
- If all of your grades in a class are 90’s and 60’s then the average will depend on the relative amounts of each.
- If you have 6 90’s and 2 60’s, then you can say that:
  - The average will be between 60 and 90
  - It will be closer to 90

Average Atomic Mass Calculations 2

- Usually based on percentages or relative amounts
- Percentages add to 100
- Relative amounts (or abundances) add to 1
  - Ex 1: 80% = .80
  - Ex 2: 6.52 % = .652
  - Ex 3: 0.5% = 0.005
  - (# sig figs stays the same)

Average Atomic Mass Sample Problem 1

- A sample of neon is analyzed in a device called a mass spectrometer and found to have the following isotope composition:
- Neon-20 (20.067 amu) = 87.3% (or .873 abundance)
- Neon-21 (21.059 amu) = 10.6% (or .106 abundance)
- Neon-22 (22.073 amu) = 2.1 % (or .021% abundance)
- Find the average atomic mass of neon to 3 decimal places

Solution 1

- First- think about a couple of things:
  - The average must be between 20 and 22
  - It will be closer to 20
- Set up looks like this:
- (mass of isotope 1)(abundance of isotope 1) +
- (mass of isotope 2)(abundance of isotope 2) +
- (mass of isotope 3)(abundance of isotope 3)

- = average mass

Set-up and calculation

(20.067 amu)(.873) + (21.059 amu)(.106) + (22.073 amu)(.021) =

17.518 + 2.232 + .463 =

20.213 amu

Check- it is between 20 and 22 and closest to 20

You could also have done with %'s (ex 20.067 x 87.3) etc

And then divided by 100 at the end. Either is fine.

The answer does not have to match the periodic table (it will be close)

Average Atomic Mass Sample Problem 2

- Same idea but here we are given numbers of atoms not %'s or abundances
- A minute sample of gold atoms is analyzed and found to have the following composition:
- Au-196 (mass = 195.894 amu) = 208 atoms
- Au-197 (mass = 196.892 amu) = 981 atoms
- Au-198 (mass = 197.879 amu) = 129 atoms
- Find the average atomic mass of gold in the sample.

Set-Up and Solution

- You could convert the number of each isotope into a percent or abundance (number of isotope over total. But you don't have to:
- Think –between 196 and 198 (close to 197)

(195.894 amu)(208 atoms) = 40745.952

+(196.892 amu)(981 atoms) = 193151.052

+(197.879 amu)(129 atoms) = 25526.391

259423.395 amu / 1318 total atoms

check for "reasonableness"

196.831 amu

Unit Wrap-Up

- Know all the people and what they contributed
- No dates are required but should know general order of things and rough ideas of timing
- Know any experiment described in detail (I have seen the test!)
- Be able to interpret atomic symbols

Unit Wrap-Up

- Be able to do average atomic mass calculations (know how to check for reasonableness of an answer)
- Be able to describe what isotopes are and recognize if two atoms are isotopes of each other